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<p>(21) International Application Number: PCT/US99/14321 (22) International Filing Date: 24 June 1999 (24.06.99) (30) Priority Data: 09/105,414 26 June 1998 (26.06.98) US (71) Applicant: EVEREADY BATTERY COMPANY, INC. [US/US]; 25225 Detroit Road, P.O. Box 450777, Westlake, OH 44145 (US). (72) Inventor: JURCA, Romulus, P.; 1954 Columbia Road, Westlake, OH 44145 (US). (74) Agent: TOYE, Russell, H., Jr.; Eveready Battery Company, Inc., 25225 Detroit Road, P.O. Box 450777, Westlake, OH 44145 (US).</p>		<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>With international search report.</i></p>
<p>(54) Title: ELECTROCHEMICAL CELL HAVING INCREASED ANODE-TO-CATHODE INTERFACE AREA</p> <p>(57) Abstract</p> <p>An electrochemical cell having a large anode-to-cathode interface area which achieves low current density to provide high cell efficiency. The electrochemical cell includes a can containing a first electrode and a second electrode. The first electrode has an outer perimeter which substantially conforms to the interior walls of the can and further has a non-cylindrical cavity provided therein. The second electrode is disposed within the non-cylindrical cavity of the first electrode. The first and second electrodes provide an interface area that varies along the length of the cell. A separator is disposed between the first and second electrodes and a cover and seal assembly is assembled to an open top end of the can.</p> <div data-bbox="1003 1142 1409 1934"> </div>		

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ELECTROCHEMICAL CELL HAVING INCREASED
ANODE-TO-CATHODE INTERFACE AREA

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The present invention generally relates to electrochemical cells and, more particularly, relates to an electrochemical cell having an increased anode-to-cathode interface area.

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Electrochemical cells are commonly employed to supply voltage for electrically operated devices, and are particularly well-suited for use with portable electrically operated devices. Currently, the popular conventional alkaline cells are of a generally cylindrical type which are commercially available in industry standard sizes including D-, C-, AA-, AAA-, AAAA-size cells, as well as other sizes and configurations.

Electrochemical cells, such as the aforementioned cylindrical type, commonly provide for a predetermined open circuit voltage supply.

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Conventional cylindrical alkaline cells generally have a cylindrical-shaped steel can provided with a positive cover at one end and a negative cover at the opposite end. The cylindrical cell has a positive electrode, commonly referred to as the cathode, which is often formed of a mixture of manganese dioxide, potassium hydroxide solution, water, and other additives, formed about the interior side surface of the cylindrical steel can. A cup-shaped separator is centrally disposed in an inner cylindrical volume of the can about the interior surface of the cathode. A negative electrode, commonly referred to as the anode, is typically formed of zinc powder, a gelling agent, and other additives, and is disposed

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along with the electrolyte solution within the separator. The aforementioned cylindrical cell is commonly referred to as a bobbin-type cell, one example of which is disclosed in US-A-5,501,924.

5 Conventional bobbin-type cells of the aforementioned cylindrical type have a single cylindrical anode and single cathode contained within the steel can and separated via the cup-shaped separator. The cathode is usually disposed adjacent to the interior side wall of a steel can, while the anode is disposed within a cylindrical cavity provided in the cathode. Accordingly, the conventional cell has a cylindrical anode-to-cathode interface
10 surface area generally defined by the shape and size of the anode and the cathode. With the conventional cylindrical cell, the anode-to-cathode interface area is approximately equal to the surface area of the cylindrical cavity formed in the cathode, into which the separator is disposed. In addition, the anode is generally provided in the shape of a cylinder with a uniformly curved outer surface generally formed parallel to the container
15 wall such that the cathode is not easily susceptible to breakage which can lead to ionic and electric discontinuity within the cell.

 A primary goal in designing alkaline cells is to increase the service performance which is the length of time for the cell to discharge under a given load to a specific voltage
20 at which the cell is no longer useful for its intended purpose. A further goal in designing alkaline cells is to increase the high rate performance of the cell. Commercially available alkaline cells commonly have an external size that is defined by industry standards, thereby limiting the ability to increase the amount of active materials that can be utilised.

Yet, the need to find new ways to increase service performance remains a primary goal of the cell designers.

It has now, surprisingly, been found that an irregularly shaped cavity in the outer
5 electrode can provide a greater inter-electrode interface, with increased benefit to current density and performance.

Thus, in a first aspect, there is provided an electrochemical cell comprising a can containing first and second electrodes, separated by a separator, the first electrode having a
10 cavity so as to contain all or part of the second electrode, wherein the cavity is shaped such as to yield a greater surface area than a regular cylinder of the same volume would provide at the inter-electrode interface.

It will be understood that the cavity in the first electrode, which is generally the
15 cathode in alkaline cells, may be of any suitable shape, and that there is no particular restriction on its configuration, other than manufacturing considerations, in general. For example, large numbers of angles might result in air pockets being formed during filling of the second electrode material but, more importantly, may result in inefficient separator lining.

20

The cavity may be formed in the form of a concertina, for example, with the corrugations angled or rounded. Rounded is preferred, but a preferred form of

manufacture is to provide cathode rings. Rounding the corners of such rings (described later) may involve an extra processing step and, so, be inefficient in cost terms.

It should also be borne in mind that application of the separator should not be unduly difficult. It can be difficult to use standard separators in the cells of the present invention. As such, it is generally preferred to use separators which only take form *in situ*, such as spray-on separators. The second electrode can then be filled after the separator has taken.

10 In general, the present invention improves the performance, and particularly the high rate performance, of an electrochemical cell by providing a cell having an increased anode-to-cathode interface area that realises low current density and achieves enhanced service performance. In another aspect, the present invention provides for an electrochemical cell including a container having a closed bottom end and an open top
15 end, and a first electrode disposed within the container and against the inner walls of the container. The first electrode has a non-cylindrical cavity and a second electrode is centrally disposed within the non-cylindrical cavity. The first and second electrodes are configured such that the shape of their interface with each other varies at one or more locations along the length of the cell. A separator is disposed between the first electrode
20 and the second electrode. A cover and seal assembly is assembled to the open top end of the container. Accordingly, the cell has a non-cylindrical first electrode-to-second electrode interface area that is greater than a cylindrical interface area, and yet provides a substantially circular radial electrode interface.

By "non-cylindrical" is meant anything that is not the shape of a regular cylinder, such as a skewed cylinder, or a cylinder with irregular cross-section along its length, for example.

5

In an alternative aspect, there is provided an electrochemical cell comprising:
a container having a closed bottom end and an open top end;
a first electrode disposed in the container, the first electrode having an outer perimeter which substantially conforms to the interior walls of the container and further
10 having a non-cylindrical cavity provided therein;
a second electrode disposed within the non-cylindrical cavity of the first electrode, wherein the first and second electrodes provide an interface area with a shape that varies along the length of the cell;
a separator disposed between the first electrode and the second electrode; and
15 a cover and seal assembly assembled to the open top end of the container.

In one preferred embodiment, the interface area has a substantially circular radial cross section. In another, the first electrode has a stepped inner surface defining the non-cylindrical cavity. In yet another, the first electrode has a tapered inside surface defining
20 the non-cylindrical cavity, the tapered surface decreasing in radial width toward the bottom end of the container.

There is also preferred an embodiment wherein the first electrode has undulations formed on the inner walls thereof to provide for the non-cylindrical cavity. In this embodiment, it is preferred that the undulations provide a varying size radial cross section of the cavity. Alternatively, it is preferred that the undulations provide a substantially
5 equal radial cross section throughout the non-cylindrical cavity.

In general, it is preferred that the first electrode comprises a cathode and the second electrode comprises an anode. It is preferred that a current collector be connected to the first electrode.
10

The separator is conveniently provided as a spray-on material, particularly when the spray-on material comprises starch.

In one embodiment, it is preferred that the first electrode comprises a plurality of
15 cathode rings having at least two different size interior diameters, the cathode rings being stacked one on top another in the container.

In a further embodiment, there is provided an electrochemical cell comprising:
a conductive can having a closed bottom end and an open top end;
20 a first electrode disposed in the container, the first electrode having an outer perimeter which conforms to the interior walls of the container and further having a non-cylindrical cavity provided therein, the non-cylindrical cavity having a substantially circular radial cross section along the length of the cell;

a second electrode disposed within the non-cylindrical cavity of the first electrode;
a separator disposed between the first electrode and the second electrode; and
the cover and seal assembly assembled to the open top end of the container.

5 There is further provided a method of forming an electrochemical cell comprising
the steps of:

providing a container having a closed bottom end and an open top end;

disposing a first electrode in the container so that the first electrode has an outer
perimeter which substantially conforms to interior walls of the container and further has a
10 non-cylindrical cavity provided therein;

disposing a second electrode within the non-cylindrical cavity of the first electrode,
wherein the first and second electrodes provide an interface area with a shape that varies
along the length of the cell;

forming a separator between the first electrode and the second electrode; and

15 assembling a cover and seal assembly to the open top end of the container.

In an alternative, there is provided a method of forming an electrochemical cell
comprising the steps of:

providing a container having a closed bottom end and an open top end;

20 disposing a first electrode in the container so that the first electrode has an outer
perimeter which substantially conforms to interior walls of the container and further has a
non-cylindrical cavity provided therein, the non-cylindrical cavity having a substantially
circular radial cross section throughout the length of the cell;

disposing a second electrode within the non-cylindrical cavity of the first electrode;
forming a separator between the first electrode and the second electrode; and
assembling a cover and seal assembly to the open top end of the container.

5 In one aspect, it is preferred that the step of disposing the first electrode and the container further includes disposing multiple cathode rings of at least two different inner diameters. In another, it is preferred that the step of disposing the first electrode in the container further comprises forming the first electrode with a tapered inside surface defining the non-cylindrical cavity such that the tapered surface decreases in radial width
10 toward the bottom end of the container.

There is also preferred the method wherein the step of disposing the first electrode in the container further comprises forming undulations in the inner walls of the first electrode to provide for the non-cylindrical cavity.

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In general, in the method of the present invention, it is preferred that the step of forming the separator comprises the step of spraying a liquid separator material on inner walls of the first electrode.

20

It should be appreciated that the present invention advantageously provides for enhanced anode-to-cathode interface surface area which provides a lower overall current density and thus results in higher cell efficiency, particularly for high rate cell

performance. It should also be appreciated that other configurations can be provided to achieve increased cathode-to-anode anode-to-cathode interface surface area.

Accordingly, electrochemical cells of the present invention provide for a non-cylindrical cathode, effectively increasing the anode-to-cathode surface interface area to achieve lower current density, resulting in higher cell efficiency and enhancing the high rate cell performance. This may be achieved, for example, by providing the cathode in a stepwise configuration, a V-shaped configuration, wave-like configuration, or other configuration providing an anode-to-cathode interface with a non-cylindrical shape that varying along the length of the cell.

The present invention will now be further illustrated with the respect to the accompanying drawings, in which:

Figure 1 is an elevational cross-sectional view of an electrochemical cell of the present invention taken through the central longitudinal axis thereof;

Figure 2 is an elevational cross-sectional view of a partially assembled cell illustrating assembly of the cell according to the present invention;

Figure 3 is a radial cross-sectional view of the partially assembled cell taken through lines III-III of Figure 2;

Figure 4 is an elevational cross-sectional view of an electrochemical cell according to a second embodiment of the present invention taken through the longitudinal axis thereof;

Figure 5 is an elevational cross-sectional view of an electrochemical cell of the present invention according to a third embodiment taken through the longitudinal axis thereof; and

Figure 6 is an elevational cross-sectional view of an electrochemical cell of the present invention according to a fourth embodiment taken through the longitudinal axis thereof.

Referring now to Figure 1, an electrochemical cell of a generally modified bobbin-type is shown having an increased anode-to-cathode interface surface area according to one embodiment of the present invention. The electrochemical cell 10 includes a positive electrode, referred to herein as the cathode, and a negative electrode, referred to herein as the anode, configured to realise a large anode-to-cathode interface area. Further, while the electrochemical cell 10 shown and described herein is a cylindrical alkaline cell, it should be appreciated that the teachings of the present invention are likewise applicable to other types of electrochemical cells having various sizes and configurations.

Electrochemical cell 10 includes a conductive container, such as cylindrical steel can 12, having a closed bottom end 14 and an open top end which is sealingly engaged with a cover and seal assembly 16. A thin layer of shrink tube insulation 18 is formed about the exterior surface of steel can 12, except for the top and bottom ends thereof. The closed bottom end 14 of can 12 may further include a positive cover (not shown) formed of plated steel with a protruding nub at its centre region which may form the positive contact terminal of the cell 10. Assembled to the open end of the steel can 12 is the cover and seal assembly 16 which forms the negative contact terminal of cell 10.

Contained within steel can 12 is the positive electrode, referred to as the cathode 20, and the negative electrode, referred to as the anode 24, with a separator 22 interfaced

with and disposed between the cathode 20 and anode 24. The cathode 20 may be formed of a mixture of manganese dioxide, graphite, potassium hydroxide solution, water, and other additives. The anode 24 may include a gel type anode formed of zinc powder, a gelling agent, and other additives and may be mixed with an electrolyte solution formed of potassium hydroxide, zinc oxide, and water. Disposed within the anode 24 is a current collector 32 which contacts zinc particles in the anode 24. The separator 22 serves as an interface that prevents the migration of solid particles between the cathode 20 and anode 24.

10 The cover and seal assembly 16 provides the closure to the assembly of electrochemical cell 10 and includes a seal body 28 and a compression member 30. The seal body 28 is generally shaped like a disk and made from electrically non-conductive material. The compression member 30 is a tubular-shaped metallic component that compresses the seal body 28 around the current collector 32. The cover and seal assembly 15 16 also includes an outer negative cover 26 welded to the exposed end of the current collector 32. The rim of steel can 12 is crimped inwardly toward the cell body to form a seal. The cover and seal assembly 16 with cover 26 may include a conventional round assembly, such as that disclosed in US-A-5,422,201.

20 The electrochemical cell 10 of the present invention employs a non-cylindrical cathode-to-anode interface which provides for an overall increase in anode-to-cathode interface surface area, in contrast to conventional cells having a continuous cylindrical anode-to-cathode interface. The anode-to cathode interface area is non-cylindrical and

non-uniform in that the shape of the interface area varies at one or more locations along the length of the cell, in contrast to a continuous cylindrical shape. While the anode-to-cathode interface area is non-cylindrical, it is preferred that the radial cross section of the anode-to-cathode interface be substantially circular throughout the entire length of the cell
5 that houses the anode and cathode materials.

The cathode 20, according to a first embodiment, is configured as a plurality of cathode rings assembled to provide at least two different size inside diameters. The cathode rings have a constant outside diameter and vary in thickness to provide the
10 different inside diameters. The first cell embodiment provides a stepped cathode configuration as seen through the longitudinal cross-sectional view.

With particular reference to Figure 2, the steel can 12 is shown having the cathode 20 assembled with a plurality of cathode rings 20A-20D stacked one on top of another.
15 The cathode rings 20A-20D are constructed according to a ring moulded cathode cell assembly. For a ring moulded cathode cell assembly, a plurality of ring moulded cathodes, such as cathode rings 20A-20D, are formed having at least two different size inside diameters. The process of forming ring moulded cathodes generally includes adding a measured charge of cathode mix to a ring shaped die set and, with the use of a die press,
20 moulding the cathode mix into the shape of a ring. The process of forming ring moulded cathodes is widely known in the art. The insertion of the ring moulded cathodes 20A-20D into can 12 may be accomplished by press fitting the bottom cathode ring 20A into the bottom portion of steel can 12. Next, the second from bottom cathode ring 20B is press fit

into steel can 12 and on top of cathode ring 20A. The third cathode ring 20C, is then inserted on top of cathode ring 20B, and the fourth cathode ring 20D is inserted on top of cathode ring 20C. Cathode rings 20A-20D are pressed into steel can 12, preferably by way of an upper punch, and arranged such that adjacent rings have different size inside
5 diameters.

Referring to Figure 3, the two lower cathode rings 20A and 20B are shown therein. The bottom cathode ring 20A has an interior surface defined by a round radial cross section of an inside diameter D_A into which the separator 22 and anode 24 are to be
10 located. Cathode ring 20A substantially conforms to the shape of the bottom portion of steel can 12. In contrast, the adjacent, second-from-bottom cathode ring 20B has an interior surface defined by a round radial cross section of an inside diameter D_B , which is larger than diameter D_A . This difference in diameters D_A and D_B provides for a stepwise interface between cathode rings 20A and 20B, and thereby increases the amount of
15 interfacing surface area that is realised between the cathode 20 and anode 24, in contrast to a continuously cylindrical anode-to-cathode interface. It should be appreciated that each of the cathode rings 20A-20D preferably provides a substantially circular radial cross section. By providing a substantially circular radial cross section of the interior surface of cathode 20, a uniform continuous surface parallel to the inside wall of can 12 is achieved, which
20 allows the cathode 20 to expand as it discharges while uniformly maintaining the shape of the cathode 20 to prevent cathode breakage. While the radial cross section shown is substantially circular, the cathode 20 has a non-cylindrical configuration as taken through

its longitudinally axis such that an increased interface surface area between the anode 24 and the cathode 20 is realised.

The anode-to-cathode interface surface area is non-cylindrical in that the interface area includes both the longitudinally extending interface area as well as the radially extending interface area formed by the area inscribed between adjacent cathode rings. According to the four cathode ring embodiment shown herein, the anode-to-cathode interface surface area is equal to the summation of the inside surface area of each of the cathode rings 20A-20D, and further summed with the radial surface area inscribed between the two inside diameters of adjacent cathode rings, including the radial surface area between cathode rings 20A and 20B, the radial surface area between cathode rings 20B and 20C, and the radial surface area between cathode rings 20C and 20D. Accordingly, the radial surface area adds to the overall anode-to-cathode interface area realised with the present invention.

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Referring again to Figure 2, also shown is a process for applying a liquid spray-on separator 22 onto the inside walls of cathode 20. The spray-on separator 22 may be applied with a disk-shaped liquid separator dispenser 34 or other suitable separator application device. The liquid separator dispenser 34 may include a tube connected to a disk-shaped nozzle which spins to apply a liquid separator material by way of centrifugal force to coat the inside surface of cathode 20. The liquid spray-on separator material may include a starch according to one example. The liquid spray-on separator may alternately include a polystyrene separator such as that disclosed in issued US-A-4,315,062. The

spray-on separator 22 preferably coats the inside walls of cathode 20 to provide a substantially uniform separator 22 that will interface between the cathode 20 and anode 24.

Once the separator 22 is formed on the interior surface of cathode 20, the anode 24 is disposed within the cavity provided in cathode 20. The anode 24 conforms to the shape of the cavity to consume the remaining volume within the interior surface of cathode 20. Once the cell materials, including the anode 24, cathode 20, separator 22, and electrolyte solution, have been disposed within steel can 12, the current collector 32 is assembled in contact with the anode 24, and the cover and seal assembly 16 is assembled to the open top end to seal the can 12.

While the first embodiment of cell 10 has been described in connection with a cathode 20 formed of four cathode rings 20A-20D, it should be appreciated that a different number of rings may likewise be provided to achieve a non-cylindrical cathode-to-anode anode-to-cathode interface with increased surface area to achieve lower current density and higher cell efficiency. According to one example of a AA-size cell, cathode rings 20A and 20C were provided with an inside diameter of 0.250 inches (0.635 centimetres) while cathode rings 20B and 20D were provided an inside diameter of 0.427 inches (1.085 centimetres), to provide an overall total cathode surface area of 2.026 inches squared (13.073 centimetres squared). According to the aforementioned example, the cell with the anode and cathode as configured achieved a 12.4 percent increase in surface area over a conventional cylindrical cell having an cylindrical cathode inside diameter of 0.350 inches (0.889 centimetres). Based on an even number of rings of cylindrical shape, the total

anode-to-cathode interface surface area can be increased by approximately eleven percent (11%) for each additional two rings. It has been found that at four rings per cell with the stepped arrangement, the performance on some high rate tests could be double compared to the present best performance obtained from a four ring uniform inside diameter cell construction. It should also be appreciated that a greater number of rings may be employed, such as six, eight, and ten rings or more. As the number of rings per cell increases, the anode-to-cathode interface surface area likewise increases. However, there is a compromise in that the thinner the rings are, the more difficult it becomes to apply the separator 22, as well as to provide proper location of the anode 24.

10

Referring to Figure 4, a second embodiment of electrochemical cell 10 is illustrated therein in which the cathode 20 is formed in a cone-shaped configuration. The cathode 20 has a tapered inside surface into which cone-shaped separator 22 and anode 24 are provided. The cathode 20 is formed with its inside surface having a taper at an angle that is preferably greater than two degrees as taken from the longitudinal axis of the cell. The cone-shaped anode-to-cathode interface area achieved with the second embodiment likewise is non-cylindrical and has a substantially circular radial cross section.

15

In Figure 5, a third embodiment of electrochemical cell 10 is shown therein.

According to the third embodiment, the cathode 20 is configured having an inside diameter that continuously varies along the length of the cell, and has a radial cross section at all sections taken through the cell. From a longitudinal cross-sectional view, the anode-to-cathode interface surface has undulations or wave-like pattern, which effectively

increases the anode-to-cathode interface surface area in contrast to that of a cylindrical cathode.

As shown in Figure 6, a fourth embodiment of cell 10 is shown in which the
5 cathode 20 maintains an inside diameter of uniform radial cross section throughout the
length of cell 10. According to this fourth embodiment, the anode-to-cathode interface
surface is non-cylindrical and continuously changes along the length of the cell to provide
increased anode-to-cathode surface area. However, the inside diameter of the cathode 20
into which the anode 24 is provided maintains a uniform diameter, which may allow for
10 ease of assembly of the anode.

Claims:

1. An electrochemical cell comprising a can containing first and second electrodes,
separated by a separator, the first electrode having a cavity so as to contain all or part of
5 the second electrode, wherein the cavity is shaped such as to yield a greater surface area
than a regular cylinder of the same volume would provide at the interface between the
electrodes.
2. An electrochemical cell comprising:
10 a container having a closed bottom end and an open top end;
a first electrode disposed in the container, the first electrode having an outer
perimeter which substantially conforms to the interior walls of the container and further
having a non-cylindrical cavity provided therein;
a second electrode disposed within the non-cylindrical cavity of the first electrode,
15 wherein the first and second electrodes provide an interface area with a shape that varies
along the length of the cell;
a separator disposed between the first electrode and the second electrode; and
a cover and seal assembly assembled to the open top end of the container.
- 20 3. A cell according to claim 1 or 2, wherein the interface area has a substantially
circular radial cross section.

4. A cell according to claim 1,2 or 3, wherein the first electrode has a stepped inner surface defining the cavity.
5. A cell according to claim 1, 2 or 3, wherein the first electrode has a tapered inside surface defining the non-cylindrical cavity, the tapered surface decreasing in radial width toward the bottom end of the container.
6. A cell according to claim 1, wherein the first electrode has undulations formed on the inner walls thereof to provide the cavity.
- 10 7. A cell according to claim 6, wherein the undulations provide a varying size radial cross section of the cavity.
8. A cell according to claim 6 or 7, wherein the undulations provide a substantially equal radial cross section throughout the non-cylindrical cavity.
- 15 9. A cell according to any preceding claim, wherein the separator is provided as a spray-on material.
- 20 10. A cell according to claim 9, wherein the spray-on material comprises starch.

11. A cell according to any preceding claim, wherein the first electrode comprises a plurality of cathode rings having at least two different size interior diameters, the cathode rings being stacked one on top another in the container.
- 5 12. A method for the manufacture of an electrochemical cell comprising the steps of:
providing a can having one open end;
disposing a first electrode in the can, the electrode having a cavity therein to
contain all or part of a second electrode, the cavity being shaped such as to yield a greater
surface area than a regular cylinder of the same volume would provide at the interface
10 between the electrodes;
and disposing a separator between the electrodes.
13. A method according to claim 12, adapted such as to provide a cell in accordance
with any of claims 1 to 11.
- 15 14. A method according to either of claims 12 and 13, wherein the step of disposing
the first electrode in the can includes disposing multiple cathode rings of at least two
different inner diameters.
- 20 15. A method according to any of claims 12 to 14, wherein the step of forming the
separator comprises the step of spraying a liquid separator material on inner walls of the
first electrode.

16. A cell prepared in accordance with the method of any of claims 12 to 15.

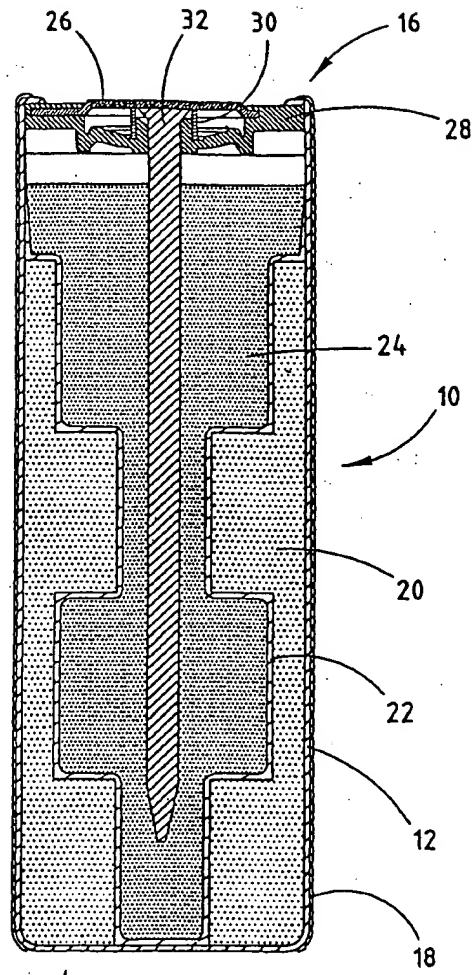


FIG. 1

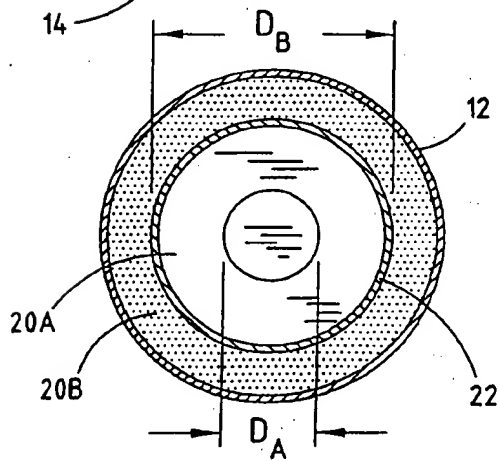


FIG. 3

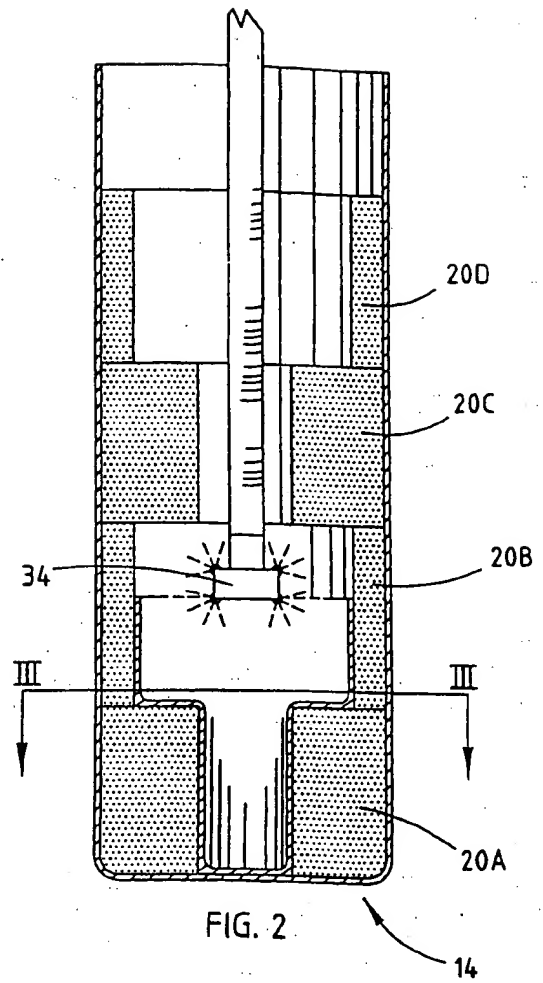
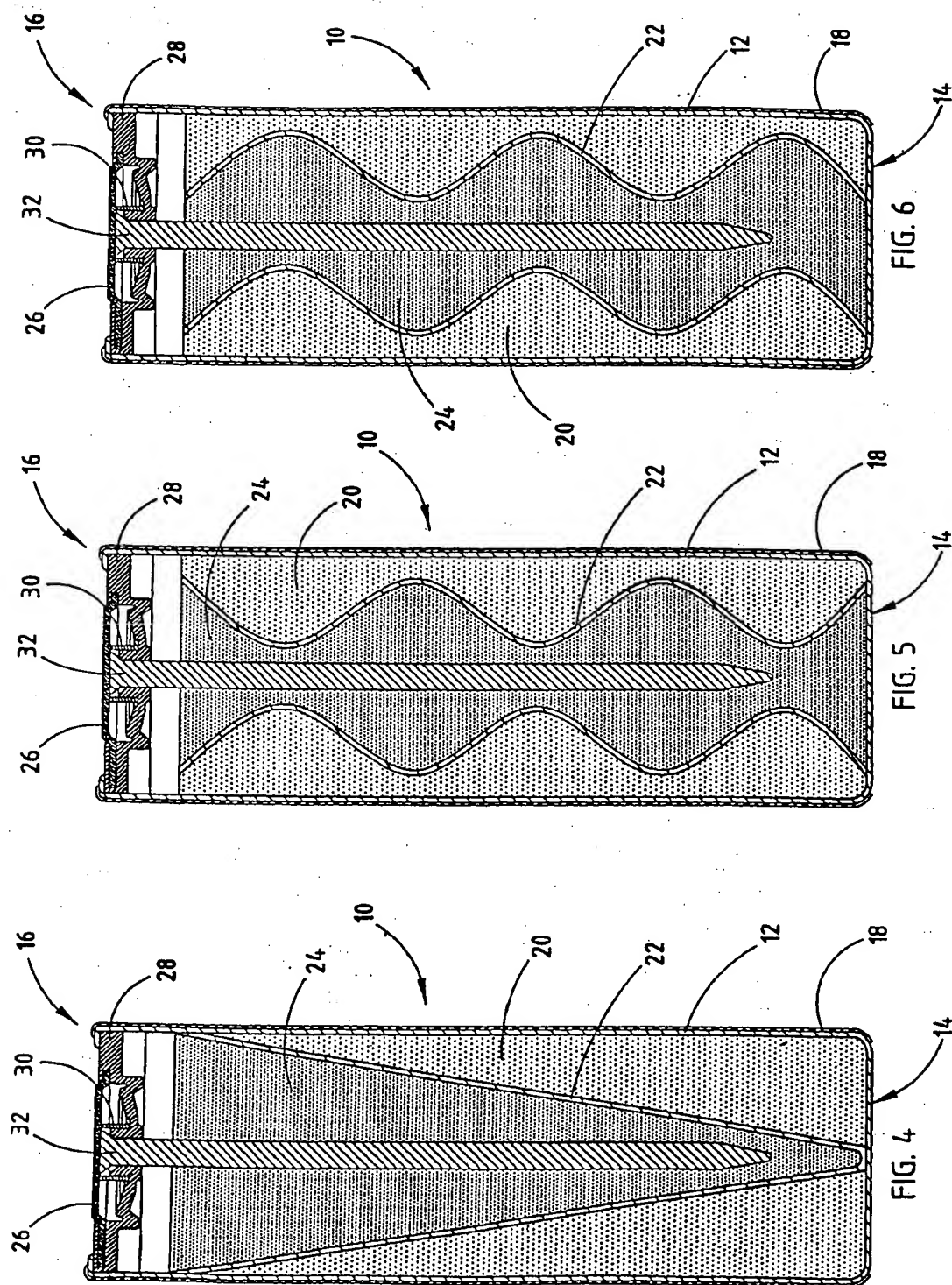


FIG. 2



INTERNATIONAL SEARCH REPORT

Internal Application No

PCT/US 99/14321

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H01M4/04 H01M6/06 H01M6/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H01M

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Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 340 653 A (ADAMS RICHARD C) 20 July 1982 (1982-07-20) column 2, line 63 -column 3, line 31 figures 1-4	1,2,12, 16
A	GB 1 285 202 A (THE EVER READY COMPANY) 16 August 1972 (1972-08-16) figures	
A	GB 2 231 196 A (TUNG KWAN CHI;LANG TSAI ING) 7 November 1990 (1990-11-07) figure 6	
A	US 4 032 696 A (URRY LEWIS FREDERICK) 28 June 1977 (1977-06-28) figures 3,4	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 99/14321

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4340653 A	20-07-1982	NONE	
GB 1285202 A	16-08-1972	NONE	
GB 2231196 A	07-11-1990	NONE	
US 4032696 A	28-06-1977	AR 214062 A	30-04-1979
		AR 218280 A	30-05-1980
		AU 506328 B	20-12-1979
		AU 2238977 A	24-08-1978
		BR 7700982 A	18-10-1977
		CA 1084990 A	02-09-1980
		CA 1095120 A	03-02-1981
		CH 615298 A	15-01-1980
		DE 2706461 A	25-08-1977
		FR 2341951 A	16-09-1977
		GB 1502251 A	01-03-1978
		GR 70651 A	03-12-1982
		IN 147274 A	12-01-1980
		JP 52100130 A	22-08-1977
		JP 57005348 B	29-01-1982
		KE 3051 A	06-06-1980
		NZ 183365 A	16-03-1981
		OA 5570 A	30-04-1981
		PH 13264 A	25-02-1980
		SU 1122241 A	30-10-1984
		US 4154905 A	15-05-1979
		ZA 7700282 A	30-11-1977